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SUBJECT TELESCOPE POINTING CONTROL POTENTIAL ERROR SOURCE SUMMARY

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(NASA-TM-110757) TELESCOPE POINTING CONTROL POTENTIAL ERROR SOURCE SUMMARY (NASA. Ames Research Center) 10 p

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To : J. Hirata 11 Oct 91
From : F. Robbins
Subject : Telescope Pointing Control
Potential Error Source Summary
cc: C. Wiltsee, R. Yee

ABSTRACT

In order to identify the error sources that can potentially degrade stabilization performance of the telescope, the following summary is offered as a guideline for use in future performance/design analysis and telescope simulation development.This list is not all inclusive but is meant to be a living document that will be updated periodically.

External Disturbances

Airframe Transmissible Vibration

o 6-DOF vibration that can result from aircraft systems (e.g. engine noise) and airframe bending and torsion modes. Vibration can be of major concern to telescope performance if the vibration PSD levels are high and not adequately isolated. Vibration perturbs the telescope residual unbalanced mass and imparts unwanted torque to the telescope which degrades pointing control performance. The vibration can also excite bending and torsion modes in the telescope which can cause image jitter irrespective of mass unbalance.The levels of this jitter are determined by the vibration isolation system attenuation capability.

Wind Disturbances (Acoustic pressure)

o This is the torque imparted to the telescope that is developed in the telescope cavity as a result of both pressure fluctuations (rms component) and pressure differential (d.c. component) on the telescope sail area.This torque is considered the major disturbance torque perturbing the telescope and must be given a very high priority when sizing the servo torque motors. (These disturbances can be reduced to some extent by proper cavity acoustic reduction techniques, but the telescope cannot be fully isolated from these effects).

Aircraft 6-DOF Kinematics

o These are the aircraft translational and rotational accelerations that perturb the telescope mass unbalance (MUB) and cause undesirable torques,

and the airframe rotational rates that induce gyroscopic torque and direct gimbal rates. These are some of the more prominent torque disturbances to the telescope and must be taken into account when sizing the pointing control torque motor

Telescope Bulkhead Mounting Deflections

- o Bulkhead deflections arise from the non-rigid bulkhead where the telescope is mounted. The torque that can be imparted to the telescope results from the spring torque inherent in the cable drape that interfaces with the telescope to provide power to the control components.

Thermal Fluctuations/Gradients

- o Thermal effects to the telescope can induce a number of undesirable properties. The most significant are rapid temperature changes that can produce expansion and contraction deflections inherent in the different telescope materials.In addition, temperature variations will generate control sensor performance degradation.

Gravitational Acceleration

- o The quasi-static behavior of the acceleration of gravity effects a number of error sources,of importance is the torque developed as a function of MUB force(e.g. gyro drift) that translates into telescope disturbance torques that must be taken into account when sizing the torque motor.

Imager Process Noise

- o Process noise is externally generated as a result of the different anomalies intrinsic to the bodies in space the imager is observing (e.g. star scintillation,sky noise).
  This noise can be detrimental to track filter performance.

Electromagnetic Interference(EMI)

- o External EMI results from conducted and radiated electromagnetic energy. This energy can have a deleterious affect on sensors and test equipment which will manifest as degraded performance.

Internal Disturbances (Mechanical)

Torque Motor Misalignment

- o Torque motor misalignment can occur as a result of using two torque motors on the same axis or one motor misaligned in a spherical configuration. The

result of a misaligned torque motor(s) is the torque being generated out plane from the desired plane developing erroneous torque commands to cross axes and compromising performance.

Coulomb Friction

- o Coulomb friction (e.g. friction from; air, hydrostatic, or electromagnetic) arises as a result of any two surfaces moving in contact.This results in highly undesirable non-linear effects which can have significant degradation affects on stabilization performance.

Cable Stiffness (Constant and dynamic)

- o Cable torques arise as a result of cable drape inherently having spring properties that are both constant, depending on initial configuration, and dynamic depending on temperature changes and the motion trajectory the cable is forced to translate/rotate through. Cable stiffness produces a restoring torque to the telescope and gives rise to the variation of telescope eigenvalues. This torque must be accounted for when sizing the torque motor in order too satisfy body displacement inputs to the telescope.

Viscous Drag

- o Viscous drag is the linear damping force that is proportional to velocity.This force can be both enhancing, or detrimental depending on the value. In general, it can be detrimental if the damping coefficient(actual/critical) is too low or too high, and can be enhancing if it is in the moderate region of .25-1.0.

Note: Damping can be linear or nonlinear. This depends on the type of damping. Some examples are:

- o Rubbing of two surfaces,dry or lubricated (Coulomb)
- o Moving a body through a fluid (viscous)
- o Forcing a fluid through an orifice (velocity squared)
- o Passing a conductor through an magnetic field (viscous)

Mass Unbalance Torques

- o Mass unbalance is the result of the telescope residual rotational mass that cannot be balanced from static/dynamic balancing, and the mass distribution changes as a function of temperature or stress deflection. This is the mass that will be acted on by environmental accelerations (e.g. gravity, vibration, airframe,etc.) to produce disturbance torques to the telescope(e.g. mass radius x (mass*centripetal acceleration, or rxF)).

Telescope Gyroscopic Torques (wxh)

- o Telescope gyroscopic torques are disturbance torques that are generated as a result of the cross product of telescope rate (w) and telescope

angular momentum (h). This amounts to unequal angular momentum about two orthogonal axes when the body is undergoing a rate about the third axis (anisoinertia torque). Additional gyroscopic torques are the result of the product of inertia angular momentum and the differential rate in an orthogonal axis (e.g. Iyz*Wz(Wz-Wy)).

Telescope Bending Modes

- o Telescope bending modes (modal or eigenfrequencies) are the result of the elastic properties of the telescope. The bending modes are critical to the design of the servo control. If the fundamental frequency (1st harmonic, eigenfrquency, or characteristic frequency), is not high enough this will limit the servo bandwidth and can compromise the robustness properties of the telescope control system.

Boresight Alignment Error (dynamic)

- o This error occurs when the boresight dynamically changes (generally in a random fashion) as a result of environmental effects (e.g. temperature). This produces erroneous commands to the pointing control system from the imager through the track filter as a boresight error.

Anisoelasticity

- o Anisoelasticity is a physical property that can produce a disturbance torque to the telescope as a result of the unequal elasticity along any orthogonal axes when linear or vibratory acceleration is simultaneously present along both those axes. This is an acceleration squared phenomena that is a function of the elastic properties, fabrication, and construction of the telescope.

Gyro Drift Errors

- o Gyro drift has a direct effect on telescope drift and stabilization error and is reduced/modified by the servo return difference function. Gyro drift errors can generally be categorized to be either random or systematic drift errors. The random component of drift error are those errors (e.g. bearing noise, float restraint torque) which cannot be compensated for and are therefore present in the system and must be considered as part of the performance budget.
  The systematic drift errors are those error sources (e.g. temperature effects,cross axis rates) that can be compensated for and will not compromise the performance budget.
  However, if some of the systematic drift errors are not compensated for one reason or another (e.g. cost to compensate acceleration sensitive drift error terms) then those remaining terms must be factored

into the performance budget in an RSS fashion.

Position Sensor Errors

- o Position sensor errors directly affect telescope position error and is reduced/modified by the pointing control system return difference function.
  These errors are the result of the position sensor (e.g. resolver,encoder) error that can not be compensated for. A resolver type position sensor which is an analog device, can produce uncertainty in position by virtue of mechanical resolution. It can also produce random error as a function of winding noise and linearity.
  An encoder would produce similar discrete type errors. The encoder can develop error as a function of the encoding resolution being a finite value (e.g. truncation as a function of n pixels for m*n dynamic range). Noise can also be generated in the encoder similar to plus or minus 1 LSB in any discrete sensor.

Internal Disturbances (Electrical)

Torque Motor Crosscoupling

- o This occurs more prominently in a spherical torque motor, but can be present in a cylindrical torque motor configuration if torque motor alignment is not carefully controlled, or if two torque motors are used too control the same axis and they have not been carefully aligned. Crosscoupling will develop out-of-plane torques that will drive the telescope to unwanted positions and compromise pointing control performance.

Torque Motor Back EMF

- o Back EMF is the electromotive force generated by the motor winding that must be overcome with the available motor terminal voltage to permit proper current flow and resultant peak torque.If variation occurs as a result of voltage change or inadequate voltage capacity the result is a variation in the commanded torque out of the motor.This will result in an undesirable disturbance to the pointing control system.

Torque Motor Ripple

- o Torque motor ripple is a repeating disturbance torque present in servo motors which is superimposed on average commanded torque. The ripple results from motor commutation of the motor during rotation in a brushtype servo motor, and as a result of the electronic commutation

in a brushless type servo motor. The ripple is usually expressed as a percentage of peak torque and is calculated as the ratio of the AC torque component to the average (or DC) component of torque.

Power Line Fluctuations (surge/ripple)

- o This can occur when aircraft power is not carefully regulated before going to the various control system power supplies.Several undesirable outcomes can result from this condition; torque motor voltage can be disrupted which will translate into torque uncertainty in the commanded output. Additional anomalies would be generated in the pointing control sensors. For example gyro motors, torquers, and signal generators can be disturbed so far as to demonstrate undesirable degradation in performance, position sensor excitation and signal generators will also be disturbed to produce degraded performance. Imagers can generate additional measurement noise, and converters can increase LSB variation. All of these disturbances are highly undesirable and will increase the telescope pointing control performance budget.

Electromagnetic Interference

- o This anomaly most often can effect the servo gyros or IMU instruments (if IMU is in close proximity to electromagnetic power sources). The gyros have a magnetic disturbance coefficient that can be as high as 0.1 deg/hr/Gauss. If not properly controlled electromagnetic interference can greatly reduce gyro or accelerometer performance (accelerometers in an IMU being used for blind pointing).
  This will lead directly to a degradation in telescope drift and pointing stabilization performance, and will also effect IMU performance if one is present.

Demodulater Noise

- o This noise is developed in the demodulation circuitry as a result of extracting the different sensor kinematic information from the sensor signal generator excitation (carrier) frequency.
  This noise is present when analog sensors are being used that employ analog outputs rather than digital outputs (e.g. some analog sensors would be; certain classes of gyros or resolvers, some discrete sensor outputs would be gyros with delta-theta outputs, and encoders with digital outputs). Generally in control system design a noise filter is designed to be located at the output of the demodulater in order to minimize the noise content from the demodulater circuitry and to minimize degradation of pointing control.

Converter Noise

- o This noise is present in hybrid systems where analog-to-digital, and digital-to-analog conversion is required.Both D/A and A/D converters will generate some noise content the system design must factor into the system performance budget. Some examples of converter noise would be quantization error,truncation, and inherent sample-and-hold delay (phase) error that will compromise stability margin of the servo loops.

Aliasing

- o Aliasing occurs in systems where data sampling is being employed. The Nyquist (Shannon) theorem for data sampling requires sampling at least twice the highest frequency of interest in order to reconstruct the original signal. Theoretically some content of high frequency noise is always folded back into the lower frequencies of interest as a result of sampling.
  The low frequency noise component produced has the same amplitude (attenuated only by low frequency dynamics or filtering) as the original noise at a frequency that is the difference between the original noise frequency and a multiple of the sampling frequency. This phenomena produces unwanted energy in the low frequencies that will manifest itself as a degradation in control system performance if not properly filtered.

Imager Measurement Noise

- o This is the noise that is internally present as a result of detector noise,electronic, and the video tracker noise.This noise can generate undesirable error to the track filter and if not adequately attenuated by the track filter will degrade servo command performance.

Internal Disturbances (Software)

Filtering

- o Notch filtering, structural filtering, noise filtering or attenuation of undesirable sources can always develop error if the filter is not of degree high enough to satisfactorily attenuate the anomaly. Theoretically signals can be removed, however, in practice this is never truly achieved. This is especially true when the filter is being computed in a finite speed computer and finite length algorithm that is time delay dependent.
  The major result of unsatisfactory filtering is the degradation of pointing control stability which manifests itself as a pointing accuracy and stabilization degradation.

Time Delay Error

- o This error source is developed as a result of the inherent quality of sample data systems that require a finite time to sample a signal and then process the signal before outputting the signal for execution. The senescence of signals in a sample data control system most prominently results in phase error to the pointing control system that can be variable with time and will compromise the stability phase margins (in high speed systems this will also lead to slow actuation of control surfaces/ mechanisms that will degrade control performance). This is an undesirable condition and must be taken into account when the pointing control stability design analysis is being performed.

Inertial Rate Integration/Quaternion Error

- o This error source is developed as a result of using algorithms that do not have adequate accuracy/precision to satisfy quaternion (direction cosine) accuracy, or inertial rate integration accuracy. This will develop inaccuracies in the rotations of coordinate frames, and in the position pointing control commands. Pointing accuracy and blind pointing will both be degraded with these error sources.

Filter Coefficient Word Length

- o This error source is always present to some degree of measure when transfer functions are being computed in the control computer. Because a finite length of transfer function coefficients is realistic,truncation of the coefficient values produce inexact transfer functions that will generate uncertainty in output commands thereby compromising pointing control performance.

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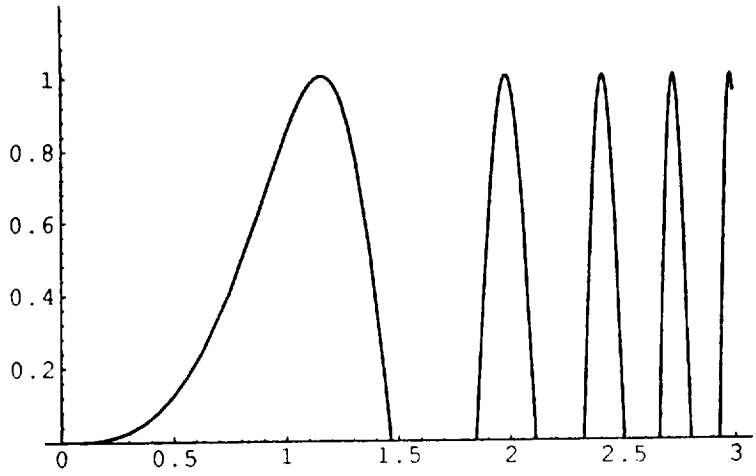

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-Graphics-
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